DRAFT

EVALUATION OF A LOSS ASSESSMENT SURVEY METHOD FOR SPRUCE BUDWORM KILLED SPRUCE-FIR IN THE LAKE STATES, 1980

by

Peter A. Rush[1],

A. Steven Munson[2],

Robert P. Ford[1]

[1]Entomologists and [2]Forestry Technician, Northeastern Area, State and Private Forestry, USDA Forest Service, St. Paul, MN

INTRODUCTION

Spruce budworm, Choristoneura fumiferana (Clemens), populations have periodically exploded in the Lake States causing tremendous spruce-fir timber losses. Because of the relatively low value of balsam fir in the past, no effort has been made to accurately estimate and document these losses. Recently, balsam fir has gained importance as a pulpwood species and there is a need for more accurate loss figures for use in planning and evaluating prevention, suppression, and salvage activities.

Heavy balsam fir losses, caused by the current spruce budworm outbreak in the Lake States, and Forest Service directives have brought about a concentrated effort to develop an operational loss assessment system. In 1979 a spruce budworm loss assessment survey method was tested by Ford (1981). The survey did not meet established accuracy criteria and took over ten person months to conduct. Recommendations from that survey which were incorporated into the present method included:

1) stratifying defoliation levels
2) using the Probability Porportional to Size (P.P.S.) technique (Lund 1978) for ground sampling
3) using a five prism point cluster for ground checking.

Loss assessment surveys, with the suggested modifications, were conducted on state and Federal lands in Minnesota and on Federal lands in Michigan and Wisconsin. These surveys were conducted by USDA Forest Service, Forest Pest Management and Minnesota Department of Natural Resources personnel during July through October 1980.

OBJECTIVES

The objectives of this evaluation were to:

1) determine the location and extent of spruce budworm infestations in the Lake States during 1980
2) complete the survey within six person months
3) use the modified P.P.S. sampling system to estimate the volume of merchantible spruce and balsam fir killed during the current spruce budworm outbreak
4) determine if survey results meet the desired level of precision, which is a standard error of the mean equal to ±20 percent (one standard deviation).

METHODS

The areas of the infestation were first mapped and stratified by defoliation level using aerial sketchmapping techniques. Sketchmapping was done in July, 1980 using a Cessna Hawk 172XP flying 1000-1500 feet (304-457 m) above ground level at a speed of 80-90 (129-145 km) miles per hour. The survey plane flew east-west flight lines at intervals of two miles (3.2 km). Defoliation was mapped for one mile (1.6 km) on each side of the aircraft to obtain 100 percent coverage of the survey area. All areas of defoliation 12 acres (4.9 ha) or larger were mapped on 0.5 inch to the mile (0.8 cm/km) Forest Service maps. The levels of defoliation were stratified as:

Stratum 1)	Light	- up to 50 percent defoliation; predominately green with some reddish-brown trees.
Stratum 2)	Moderate	- 51-80 percent defoliation; generally reddish-brown trees with no more than 10 percent appearing gray.
Stratum 3)	Heavy	- 81-100 percent defoliation; red-brown to gray cast with greater than 10 percent of the trees appearing gray.

The areas mapped as heavy defoliation were subsequently examined on the ground. The ground phase of the survey also included map data analysis (acreage tabulation according to ownership and defoliation levels) and sample selection, as well as variable plot data collection. Acreages of defoliation were determined using dot grids on the survey maps. After completing map analysis, the heavily defoliated areas within each ownership were numbered and listed with individual and accumulated acreages. From these lists the stands to be sampled were selected using the P.P.S. method.

Ground sampling was limited to the heavily defoliated areas where most of the spruce budworm caused mortality would normally occur. A cluster of five temporary sample points was used to determine host species and their relative abundance, the condition of the defoliated trees, the cause of mortality observed, and the estimated spruce and fir volume losses per acre. A sample plot consisted of a randomly placed center point and four satellite points located approximately two chains (40.2 meters) from the center point in the cardinal directions. Merchantable (trees 5 in, 12.7 cm, d.b.h. or greater) live, risk, and dead spruce and balsam fir were examined. Tally trees were within a variable-radius plot defined by using a 10 basal area factor prism.

The following data were recorded on spruce and balsam fir: the number of trees, tree species, and tree condition. Tree condition was described as live, risk (a tree that would die within two years), or dead. Only trees apparently killed by the spruce budworm during 1980 were recorded. Several factors were considered in determining how and when the tree was killed. Gray tops with some retention of red needles; the presence of fine twigs, brown coloration of the cambium; and reasonably tight bark with current wood sawyer activity are all good indications that the tree was recently killed.

The number of merchantible 8 foot pulp sticks to a 4-inch (10.2 cm) dib top were also recorded and from these data the volume lost was calculated using the following formula by Ashely (1980).

$$\text{cords per acre} = \frac{\text{Number of 8-foot sticks in countable trees} + \text{number of countable trees}}{2 \times \text{number of points sampled}}$$

For the purpose of this study, cubic foot loss was based on 128 cubic feet per cord because estimates were based on standing trees. Descriptive information on land ownership and location was also recorded.

Appendix A contains examples of all the calculations to perform when planning and conducting this loss assessment survey.

RESULTS

Approximately 6.8 million acres (2.8 million hectares) were surveyed at a cost of about $14,500.00 or 0.2 of a cent per acre. One thousand person hours (5.8 person months) were used in planning, preparing, and conducting the aerial and ground phases of the survey.

The aerial phase of the survey revealed that over 1.3 million acres (539,000 ha) received light to heavy defoliation by the spruce budworm in 1980 (Table 1).

Table 1.--Spruce-fir defoliation caused by spruce budworm in the Lake States, 1980

Land Ownership Classification	Acres			
	Light Defoliation	Moderate Defoliation	Heavy Defoliation	Total Defoliation
Michigan				
National Forests	25,447	42,394	83,441	151,282
State & Private[1/]	67,763	145,496	424,668	637,927
Minnesota				
National Forests	6,871	4,204	502	11,577
State & Private[1/]	29,399	42,628	19,470	91,497
Wisconsin				
National Forests	29,210	68,480	111,108	208,798
State & Private[1/]	63,655	76,235	90,439	230,329
Total				
National Forests	61,528	115,078	195,051	371,657
State & Private[1/]	160,817	264,359	534,577	959,753
Grand Total	222,345	379,437	729,628	1,331,410

[1/] Includes acreages of State and private lands surveyed by Forest Pest Management within National Forest boundaries as well as acreage estimates provided by state cooperators.

Evidence of spruce budworm infestations were found at all 80 plots examined on the ground and spruce-fir mortality was found on 84 percent of those plots.

Loss estimates were determined by multiplying the number of acres of heavily defoliated spruce-fir by the mean number of dead cords per acre for that particular area, (ie. National Forest or State and Private land). Loss estimates, based on these aerial and ground observations are presented in Table 2.

Table 2.--Estimated losses caused by spruce budworm defoliation in the Lake States, 1980

State	Losses - thousand cubic feet		
	National Forest	State & Private	Total
Michigan	20,056	86,972[1/]	107,028
Minnesota	103	4,658	4,761
Wisconsin	22,721	18,522[1/]	41,243
Total Lake States	42,880	110,152	153,032

[1/]These loss estimates are based on acreages provided by state cooperators and on mean mortality estimates obtained on this survey.

Standard errors of the means for individual sampling areas (ownership classes) ranged from 0.40 to 0.58 cords per acre, higher than the 0.25 cords per acre stated in the objectives; however, treating all areas surveyed as a whole, the survey method met the established accuracy requirements with a standard error of the mean equal to 0.22 cords per acre (Table 3).

Table 3.--Spruce budworm loss assessment survey statistics, white spruce and balsam fir, Lake States, 1980

Sampling Area	no. of samples	mean total volume	mean dead volume	Std. error mean dead	volume range dead
			cords/acre		
Minnesota S&P	16	15.71	1.89 ± 2.31	0.58	0.0-6.4
Nicolet NF	16	9.19	1.55 ± 1.49	0.37	0.0-5.5
Chequamegon NF	16	11.57	1.73 ± 2.71	0.68	0.0-8.5
Hiawatha NF	16	12.83	2.09 ± 1.59	0.40	0.3-5.3
Ottawa NF	16	10.86	1.81 ± 1.60	0.40	0.0-5.1
Total Lake States	80	12.03	1.81 ± 1.96	0.22	0.0-8.5

DISCUSSION

One of the objectives of this survey was to determine the location and extent of spruce budworm infestations in the Lake States. This survey method accomplished that objective. The area of the outbreak was defined and the defoliation within that area stratified at the same time.

Stratification permits ground sampling to be concentrated in areas of heavy defoliation where most of the spruce-fir mortality would normally occur. An earlier loss assessment survey (Ford 1981) failed to meet accuracy criteria because too much time was spent sampling undamaged or lightly defoliated spruce-fir stands.

Data collected on the ground confirmed the accuracy of the aerial stratification. Only 13 of the 80 heavily defoliated plots examined on the ground exhibited no mortality. Even through this figure is higher than we would like, of those 13 plots with no mortality, all but 3 did contain trees in the risk category.

Probably the greatest source of error for this survey system are the mapping errors inherent in aerial sketchmapping. These mapping errors include incorrect plotting of defoliation, omitting defoliated areas, inadvertantly including undefoliated areas, or judgement errors in classifying defoliation levels. Any one, or combinations, of these errors can affect survey results considerably.

Some plotting errors can be reduced by choosing the best type of survey map. The larger the scale and the greater the detail, the easier it is for an observer to accurately plot the location of ground information (USDA Forest Service, 1970). However, very large scale maps become difficult to handle in the confines of a small airplane cabin. Therefore, map selection should be based on best compromise between the detail associated with larger scale maps, and the manageability of map size associated with smaller scale maps. The 0.5 inch to the mile (0.8 cm/km) scale used in this survey was selected due to its practicability and availability; however, a somewhat larger scale map might have increased plotting accuracy.

Inaccuracies associated with judgment errors in defoliation stratification are more difficult to deal with. Sun angle and reflected light influence the appearance of crown discoloration considerably. To minimize these effects, early morning and late afternoon sketchmapping should be avoided. The period between 9 am and 3 pm in early to mid July is the optimum time for sketchmapping.

Even with these shortcomings, which are no different than with any other sketchmap type survey, this survey system has the important advantage of being relatively inexpensive. The cost of aircraft, travel and per diem, and salaries was only 0.2 of a cent per acre (0.5 cents per hectare) and this could be reduced even more as the system is further refined or as the users become more familiar with it through repeated use.

A second objective was to complete this survey in six person months or less. It was completed in 5.8 person months, a considerable reduction from the 10 + person months spent conducting last years survey.

The other two objectives were to use a modified PPS sampling system to estimate volume losses and to do so with a precision level of ± 20 percent of the standard error of the mean. The PPS sampling system was used and although we did not achieve the desired precision for the individual sampling areas (Forests or states) we did achieve it for the overall survey area.

Two probable reasons for unacceptable standard error of the means for the individual sampling units are: 1) population variance was greater than initially estimated, and 2) some of the prism points fell outside of host type.

When calculating the number of samples necessary, it is important to have a reasonably good estimate of population variance. In this survey we estimated a range of 0-4 cords of dead spruce-fir per acre (a variance of 1) based on last years survey. In reality this ranged from 0-8.5 dead cords per acre (a variance of 4.5). Because of the larger variance, the number of sample plots was insufficient to accurately estimate losses for the individual Forests but was adequate when the data were combined for the entire survey area. If the highest possible expected variance were used in computing the number of samples to be taken, the likelihood of obtaining acceptable results is much higher. In this case, host stocking levels ranged from 0-12 cords per acre so a range of 12 (an estimated variance of 9) should have been used in computing the number of samples necessary.

Accuracy would also be increased if all the prism points in a sample plot fell in host type. We often encountered the situation where random placement of a five point cluster caused one, or some, of the points to fall outside of host type causing a zero mortality count where mortality would normally be expected. This occurred because the spruce-fir stands were often long narrow strips that ran along lakes, streams, rivers, or ridges. Perhaps some form of systematic or authoritative sampling could eliminate or reduce this source of error.

CONCLUSIONS AND RECOMMENDATIONS

This is the best method currently available for assessing spruce and balsam-fir losses caused by spruce budworm in the Lake States. The system met the established objectives and most accuracy criteria while providing an estimate of spruce-fir losses. We should continue to use this survey method when loss assessment data are required. This survey system is a good start but it can be improved even further. The following recommendations may improve the precision and efficiency of the survey:

1) Treat each forest or private land survey area as a stratum of one large survey rather than as several separate surveys. Then, calculate the number of samples necessary on the basis of the total area surveyed. Samples would be distributed throughout the areas of heavy defoliation, proportional to the size of the strata (Forest, State, or private ownership). This should help to reduce the number of samples necessary.

2) Consider using a systematic sampling system that would insure that all sample points fell within host type.

or

Consider using separate sampling points (all in host type) rather than a cluster which is sometimes dimensionally larger than the stand of host type.

3) Use the largest possible range, the cords of host type per acre, when calculating or estimating population variance.

4) Where possible, use a map scale of one inch to the mile.

5) Sketchmap between 9 am and 3 pm.

SAMPLE CALCULATIONS FOR A STRATIFIED
PPS SPRUCE BUDWORM SURVEY

Based on our recommendations, the following is an example of the calculations necessary to determine sampling intensity and distribution:

Determine expected stratum variance:

$S_s^2 = (\frac{R}{4}s)^2$ where R_s, the range of mortality in cords per acre, will be given a value of 12 for all strata (the widest possible range of 0-12 cords) in order to obtain accurate survey results. Therefore, S_s^2, the expected variance will equal 9 cords per acre.

Establish error limits:

E, the error value, is set at ± 20 percent of the sample mean, at one standard deviation. Assuming mean spruce-fir mortality of 2 cords per acre, an error of 0.4 cords per acre will be accepted.

Considering these values and the aerial data we construct the following summary:

Appendix Table 1.--Strata statistics

Stratum	Acres in heavily defoliated stratum A_s	Stratum variance S_s^2	$A_s^2 \times S_s^2$
S & P Area A	19,000	9	171,000
National Forest A	85,000	9	765,000
National Forest B	24,000	9	216,000
S & P Area B	112,000	9	1,008,000
National Forest C	65,000	9	585,000
	305,000		2,745,000

From the summary table data, the number of sample clusters required is calculated using the formula:

$$N = \frac{\varepsilon A \times \varepsilon(A \times S^2)}{(\varepsilon A^2 \times E^2) + \varepsilon(A \times S_s^2)}$$

Where: N = Number of sample clusters

A = Total acres/ownership in the heavy defoliation category

S^2 = Expected variance

E = Allowable error

we find 57 samples are required. For purposes of comparison, if an allowable error of ±0.15 percent (0.3 cords per acre) were used, 100 samples would be required.

Using the formula:

$$N_s = \frac{A_s}{\varepsilon A_s} \times n$$

to determine the distribution of the samples between strata (and rounding up to a whole sample) we find:

Appendix Table 2.--Sample distribution throughout strata

	Samples per stratum E = ±0.20	Samples per stratum E = ±0.15
S & P, Area A	4	7
National Forest A	16	28
National Forest B	5	8
S & P Area B	21	37
National Forest C	13	22
Total	59	102

These samples are then systematically distributed within the strata using the tables of accumulated acres prepared during map analysis (Appendix Table 3).

Sampling interval is determined:

$$I_s = \frac{A_s}{N_s} = \text{a a whole number} + \text{a remainder } (r)$$

For example, National Forest A calculations would be:

$$I_s = \frac{85,000}{28} = 3035 + r \text{ of } 20$$

A random start (taken from random number tables) is selected between 1 and 3055 ($I_s + r_s$). From this start of 2485 for example, sample sites are determined by the interval of 3035 acres as it falls on the table of accumulated acres.

Appendix Table 3.--A listing of infestation areas and accumulated areas within National Forest A.

Site No.	Size (Acres)	Accum. Acres	Sample Sites	Site No.	Size (Acres)	Accum. Acres	Sample Sites
01	428	428		33	3,402	38,607	*
02	673	1,101		34	642	39,249	*
03	1,255	2,356		35	1,623	40,872	
04	378	2,734	*	36	2,194	43,066	*
05	1,620	4,354		37	386	43,452	
06	957	5,311		38	3,137	46,589	*
07	843	6,154	*	39	445	47,034	
08	1,106	7,260		40	136	47,170	
09	1,854	9,114	*	41	1,469	48,639	*
10	180	9,294		42	693	49,332	
11	2,201	11,495		43	840	50,172	
12	65	11,560		44	1,989	52,161	*
13	42	11,602	*	45	3,634	55,795	*
14	1,430	13,032		46	1,655	57,450	*
15	887	13,919		47	2,707	60,157	*
16	356	14,275		48	141	60,298	
17	1,838	16,113	*	49	717	61,015	
18	1,717	17,830	*	50	1,128	62,143	
19	1,420	19,250		51	2,485	64,628	*
20	1,309	20,559		52	1,312	65,940	
21	923	21,482	*	53	1,121	67,061	*
22	625	22,107		54	1,482	68,543	
23	727	22,834		55	1,690	70,233	*
24	1,524	24,358	*	56	5,241	75,474	2*
25	1,057	25,415		57	916	76,390	
26	568	25,983		58	404	76,794	
27	1,821	27,804	*	59	121	76,915	
28	1,376	29,180		60	444	77,359	
29	1,288	30,468	*	61	1,829	79,188	*
30	1,734	32,202		62	1,415	80,603	
31	809	33,011	*	63	1,561	82,164	*
32	2,194	35,205		64	2,836	85,000	*

LITERATURE CITED

Ashley, Burl S. 1980.

Reference handbook for Foresters. USDA Forest Service, NA, S&PF, NA-FR-15, 35pp.

Ford, Robert P. 1981.

Evaluation of a method to determine spruce-fir mortality caused by spruce budworm in the Lake States, 1979. USDA Forest Service, NA, S&PF NA-TP-7, 4pp.

Lund, H. Gyde, 1978.

Type maps, stratified sampling and P.P.S. USDI Bureau of Land Management, Denver Service Center, Denver, Colo., Resource Inventory Notes, BLM 15, 14pp.

USDA Forest Service. 1970.

Detection of forest pests in the Southeast. USDA Forest Service, SA, S&PF, SA-S&PF-7, 44pp.